

HEALTH STATISTICS

FROM THE U. S. NATIONAL HEALTH SURVEY

Hospital Utilization in the last year of life

Development and test of a method of measuring the effect of omitting decedents from a survey of hospitalization.

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The U. S. National Health Survey is a continuing program under which the Public Health Service makes studies to determine the extent of illness and disability in the population of the United States and to gather related information. It is authorized by Public Law 652, 84th Congress.

CO-OPERATION OF THE NATIONAL OFFICE OF VITAL STATISTICS

Under legislation establishing the National Health Survey, the Public Health Service is authorized to use, insofar as possible, the services or facilities of other Federal, State, or private agencies. The methodological study in this report was performed under a reimbursement agreement with the National Office of Vital Statistics, Public Health Service.

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PREFACE

A major phase of the U. S. National Health Survey is the collection of data by means of family interviews on health matters. This interviewing is carried on each week of the year throughout the Nation in a sample of households. Each household is interviewed only once and the interview questions relate only to the household members who are alive at the time of interview. A number of the questions are concerned with the family members' illness and medical care experience over a period of time ending with the Sunday before the interview, i.e., over a reference or recall period.¹ A recall period as short as the past 2 weeks is used for questions on acute illness, but for hospitalization the questions seek to elicit information on every episode in the past 12 months.

When the 12-months' data are collected only for living persons, the estimates of hospitalizations and associated hospital stays relate only to persons who have survived until the interview. These persons constitute the major part of but not the entire population exposed to the risk of being hospitalized during the 12 months in question. The persons who have died during the 12-month reference period will have accounted for a significant part of the total hospital utilization during that time. Therefore, their experience needs to be included to estimate properly the amount of hospitalization associated with specific conditions, as well as the total amount of hospital utilization during a year.

For a number of reasons, household interviews are not satisfactory for collecting data concerning persons who have died. Therefore, the National Health Survey arranged for a study by the National Office of Vital Statistics to develop and test a method of data collection and estimation to fill this gap in hospitalization data. The method to be explored was based on follow-back inquiries starting from death certificates. As a result there has been developed and demonstrated a practical method for obtaining the data and estimating the specific portion of decedent experience which must be added to the data on the living population so as to produce estimates of total hospital utilization over any specified reference period. This method is described in the following report prepared by the National Office of Vital Statistics.

¹For an explanation of the time references in the household interview see U.S. National Health Survey, Concepts and Definitions in the Health Household-Interview Survey, Health Statistics, Series A3, PHS Publication no. 584-A3, Public Health Service, Washington, D.C. Sept, 1958.

The report presents a theoretical formulation of the problem under study. A method of data collection and a test of it are described, the data are presented, and the theory is applied to them. For the sake of economy, the data collected were confined to deaths during a single month. This necessitated the adoption of certain assumptions that would become unnecessary if deaths over an entire 12-month period were to be used. The formulation also advantageously utilizes the entire experience during the last year of life in the estimation process, and consequently a small sample of decedents will suffice.

The data in this study were derived from a sample of one month's deaths in the 3 Middle Atlantic States. They are presented only to illustrate the method. The reader is, therefore, cautioned against using any of the numerical estimates as indicative of actual experience even for the Middle Atlantic region.

* * * * *

For the special studies which are carried out at its expense but are not directly conducted by the National Health Survey, a staff member is assigned for liaison with the research organization doing the study. In addition to keeping closely informed on the study progress and conveying the National Health Survey's viewpoint in decisions on study methodology, the liaison person edits the final research report for publication in Health Statistics, Series D. For this study, Mr. Earl Bryant of the Special Studies staff discharged these responsibilities.

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HOSPITAL UTILIZATION

in the last year of life

(The following research report was prepared in the National Office of Vital Statistics, U.S. Public Health Service, by Monroe G. Sirken, who directed the research project. Acknowledgment is due Morton L. Brown, who gave valuable assistance in the Mortality Survey, also to Karol Walsh and Gustav Carlson, who assisted in computations of sampling error, and to Ruth Crocker, who assisted in the Mortality Survey. The National Office of Vital Statistics conducted the project under a contract with the U.S. National Health Survey.)

THE RESEARCH PROBLEM

This report presents the results of a research project undertaken for the purpose of developing and testing a procedure for obtaining estimates of hospital utilization by decedents. The U. S. National Health Survey covers only the experience of persons living at the time that household interviews are conducted. Consequently, to obtain estimates of total hospital utilization by the population, it is necessary to supplement the hospital data collected in the health survey with similar data for decedents.

The Method of Study

A specific survey method for collecting the needed data was investigated. It was a survey "anchored to the death record"¹ in which information on hospital utilization during the last year of life was collected by following back to sources of information identified on the death certificate and to others identified by these sources. The essentials of this survey method as applied to this problem are:

- (a) selecting a probability sample of deaths from the files of registered death certificates,
- (b) conducting surveys of the death certificate informant and the hospital in which death occurred, both of which are identified on the death certificate, and of other potential sources identified by the death certificate sources,
- (c) collecting information on the episodes of hospital utilization during the 1-year period prior to death for the decedents in the sample,
- (d) deriving unbiased estimates of the volume of general hospital utilization by

decedents not covered in the household interviews of the U. S. National Health Survey, and the variance of these estimates.

There were two distinct but interrelated problems of the research project. First it was necessary to develop an appropriate stochastic model and to derive a formula which would provide efficient and unbiased estimates of hospital utilization by decedents which is not covered in the household interviews of the National Health Survey. Also, it was necessary to develop and test a design for a mortality survey that would, at the lowest cost, provide accurate data for estimating the parameters specified by the stochastic model.

The stochastic model specified the process for obtaining, from the Mortality Survey, unbiased estimates of hospital utilization by decedents not covered in the health survey and the sampling variability of the estimates.

The design of a mortality survey was tested in a survey conducted in the Middle Atlantic States involving several hundred deaths. The pilot study provided information for comparing the accuracy and costs of estimates of hospital utilization by decedents based on (a) different sampling designs, (b) different data collection methods, and (c) different sources of information.

Hospital Utilization Not Covered in Household Surveys

A discussion in a National Health Survey publication of the limitations of national estimates of hospital utilization derived from the U. S. National Health Survey,² cautions that "Since the survey data refer only to persons who

were alive at the time of interview, the hospital experience of persons who died in the year prior to the interview period is not counted." In view of the objectives of this report it is appropriate, if not essential, to clearly define the hospital utilization by decedents which is not covered in the health survey. This will require a brief summary of the statistical design of the U. S. National Health Survey.³

The National Health Survey Program conducts a weekly survey of a national sample of households that is representative of the civilian noninstitutional population. For each person residing in sample households on the enumeration date, the interviewers collect information on hospital utilization during the preceding 12-month period. (The 12-month period preceding the week of interview is called the reference year in this report. The estimates of hospital utilization by both decedents and by persons interviewed in the National Health Survey refer to utilization during the reference year.) Two recall questions elicit information on the number of times each person in the household had been hospitalized "during the past 12 months." For each hospital episode, a series of questions are asked including those which establish the month of admission and the length of stay. Estimates of hospital utilization during the reference year are derived from the survey reports collected from a series of consecutive weekly samples.

The reports collected in each interviewing week provide estimates of the hospital utilization during the preceding 12-month period by persons who were alive at the time of interview. The health survey does not cover the experience of persons who had died prior to the interview. Specifically, the estimates of hospital utilization derived from the health survey exclude the hospital utilization during the 12-month period prior to the interviewing week of the persons who died in that period. Henceforth, the volume of hospital utilization by decedents not covered in the estimates derived from the health survey will be referred to as the volume of hospital utilization by decedents during the reference year. For example, national estimates of hospital utilization referring to the 12-month period, July 1957-June 1958, derived from the household interviews of the National Health Survey would not include the volume of hospital utilization during this period by persons who died between July 1957 and June 1958. The factors needed to adjust these data to include the utilization by decedents and thereby obtain estimates of total hospital utilization are unknown. Preliminary estimates of these adjustment factors based on the Mortality Survey conducted in the Middle Atlantic States will be presented subsequently in this report.

Adjustments Derived From Other Studies

Two reports of independent research dealing with the problem of undercoverage of hospital utilization by persons prior to death in estimates derived from health surveys have been published.^{4,5} Both reports were concerned with the results of health surveys in which information on hospital utilization was collected retrospectively for a 12-month period prior to the enumeration date for the living population. Both reports indicated that adjustment of the estimates derived from the health survey to include the hospital utilization of decedents was substantial, particularly for the population at the older ages.

To adjust the estimates of the national volume of hospital care based on a survey of hospitalization which had been conducted in March 1952, as a supplement to the Current Population Survey by the Bureau of the Census, Falk and Brewster⁴ made crude estimates of the volume of hospital care received by decedents 65 years of age and over. First, they estimated the proportion of deaths at ages 65 years and over which occurred inside and outside hospitals. Then they assumed specified hospital admission rates and lengths of stay per admission for deaths which occurred inside and outside hospitals. The addition of this volume of care received by decedents to the estimates for persons 65 years and over based on the household survey increased the volume of admissions and days in the hospital by approximately one fourth.

Siegel, Belloc, and Hesse⁵ estimated the volume of hospital care received by decedents who died between July 1, 1951 and June 30, 1952, in order to adjust the estimates of the volume of hospital care based on a household survey in San Jose, Calif. They estimated the volume of hospital care received by decedents by a procedure which involved matching the death records for deaths that occurred between July 1, 1951 and June 30, 1952, with the hospital records of persons who received care during the same period in four general hospitals serving the population of San Jose. Their adjustments of the estimates based on the health survey of the San Jose population for the experience of persons who died increased hospital admissions by 6 percent and hospital days by 10 percent (table 1). For persons 65 years of age and over, the adjustment increased both the rate of admissions and the rate of days in the hospital by approximately one third.

Compared with statistics on hospital utilization, other health statistics derived from the household survey would in all likelihood be considerably less affected by the omission of the experience of decedents. This point is worth mentioning since the findings to be reported subse-

Table 1. Annual rates of admissions and days in general hospitals per 1,000 population by sex and age, unadjusted and adjusted to include the experience of decedents not counted in the California Health Survey: San Jose, May 1954-April 1955

Sex and age	Admissions			Days		
	Rate per 1,000 persons		Percent increase	Rate per 1,000 persons		Percent increase
	Unadjusted	Adjusted		Unadjusted	Adjusted	
Both sexes-----	93	99	6	881	969	10
0-44-----	90	91	1	685	705	3
45-64-----	98	106	8	1,151	1,272	10
65+-----	109	146	34	1,900	2,493	31
Male-----	70	76	9	968	1,050	8
0-44-----	56	57	3	709	725	2
45-64-----	101	111	10	1,451	1,563	8
65+-----	121	162	34	2,018	2,609	29
Female-----	114	119	4	798	892	12
0-44-----	121	122	1	662	685	3
45-64-----	94	101	7	862	991	15
65+-----	98	131	34	1,792	2,386	33

Source: Siegel, B.M.; Belloc, N.B.; and Hesse, F.E. Household surveys for hospital planning: Adjustment for decedents missed. Pub. Health Rep. 72: 993, Nov. 1957.

quently deal entirely with hospital utilization. In the household interview of the National Health Survey, information concerning hospital utilization is collected for a 12-month period preceding the week of enumeration, whereas, for most other health characteristics collected in the household

interview, the information is collected for a prior 2-week period. Additionally, compared with most other health characteristics collected in household interviews, hospital utilization is probably more strongly linked to the subsequent occurrence of death.

THE MORTALITY SURVEY

A mortality survey was conducted in the Middle Atlantic States to develop and to test a survey method for collecting information on hospital utilization during the last 12 months of life. The information was collected retrospectively for a sample of persons whose death occurred in the Middle Atlantic States during April 1957. These data would be used to derive estimates of the volume of general hospital utilization by decedents during a specific 1-year reference period. (That is, the volume of hospital utilization

during a specified 12-month period by persons who died during that period.) It should be noted that only part of the utilization during the last 12 months of life occurs during the reference year. In considering a specific reference period, for example, a calendar year, only the utilization during the last week of life falls into the reference period for those dying at the end of the first week of the reference period, only the utilization during the last two weeks for those dying at the end of the second week, and so on.

SAMPLE DESIGN AND SURVEY PROCEDURES

A sample of 695 death certificates was selected from the shipments of death certificates in the Current Mortality Sample which arrived in the National Office of Vital Statistics during May 1957.* A systematic sample of every fourth certificate in this shipment from the registration areas in the Middle Atlantic States was selected. Thus, the sample consisted of about 2½ percent of deaths for which April 1957 was the principal

*The Current Mortality sample is a 10-percent sample of death certificates which is transmitted monthly to the National Office of Vital Statistics (NOVS) by each of the 54 independent areas for registering deaths. The certificates are selected systematically from the files of death certificates registered in the central office of the registration area. The shipments of certificates in the Current Mortality Sample which arrive in NOVS toward the end of each month relate to deaths for which the previous month is the principal month of occurrence.

month of occurrence. The distribution of the deaths by place of occurrence is shown below:

Registration area	Number of sample deaths
Total	695
New York City	172
New York (excluding New York City)	177
Pennsylvania	235
New Jersey	111

The principal sources of information were persons who provided personal information about the decedents for the death certificate (informants) and the hospital in which they received medical care. The informant is generally some close relative of the decedent. In some instances, the address of an informant could not be identified. For such cases, the funeral director was asked to identify some close relative of the decedent. By and large this "relative" had been the death-certificate informant. Surveys of these sources were conducted during the 6-month period, June-November 1957 (table 2).

Table 2. Schedule of data collection by source of information and type of survey

Period during 1957	Principal sources of information	Type of survey	Sample size
June-----	Funeral directors	Mail	208
July-August-----	Relatives of decedents (informants)	Mail	643
	Medical institutions in which deaths occurred	Mail	423
September-October-----	Referral hospitals	Mail	196
November-----	Nonresponding informants to the mail survey	Personal interview	86

Survey of Funeral Directors

Space is provided on the standard death certificate (fig. 1) for the signature and the address of the informant (item 17) and for the name and address of the funeral director (item 24). For about 30 percent of the deaths in this study, however, it was not possible to establish the name and mailing address of the informant from

the death certificate because this information was not entirely legible or complete. Consequently, a mail survey was conducted with funeral directors to obtain this information. On completion of a regular and certified mail follow-up, the response rate was about 97 percent. (The interval between original and followup mailing was 2 weeks for each of the sources of information surveyed in this study.)

For each reported admission, the following information was requested:

Periods of care	Admitted	Discharged	Diagnosis	Operations performed
Period	Month	Month		
	Day	Day		
	Year	Year		
				<input type="checkbox"/> None

The institution of death was also asked if it had knowledge of other medical institutions in which the decedent had received care.

- A. According to your records or to your personal knowledge, was the deceased a patient in any other hospital, nursing home, or sanitarium between January 1, 1956, and the date of death?
1. ☐ Yes 2. ☐ No 3. ☐ Don't know

For each other institution reported, the following information was requested:

Name _____
City or place _____
County _____
State _____
Approximate admission date _____

The returns from the family informants and institutions in which death occurred were

screened for information identifying institutions in which the decedent was reported to have received nonterminal care during a period between January 1, 1956 and death. A mail survey, involving essentially the same form mailed to institutions providing terminal care, was conducted with these institutions as well as with the additional institutions which they in turn identified. In this manner, the mail survey of referral institutions included every institution which was reported by any source to have provided nonterminal hospital care to the decedent. The response rate for general hospitals (exclusive of the hospitals providing terminal care) was about 65 percent after the initial mailing and about 97 percent after a certified mail followup.

Editing Procedures

Editing procedures comprised an essential step in processing the returned forms. When the form from a funeral director or hospital or family informant was returned, it was edited for completeness and consistency. If the form was evaluated as providing inconsistent or incomplete information a special letter was mailed to collect further information. In the event that it was felt that the family informant whose form failed edit would be unable to supply the supplementary information, queries were sent to another relative of the decedent if one had been identified either by the funeral director or the informant himself.

EXPERIMENTAL FINDINGS FROM THE MORTALITY SURVEY

In the Mortality Survey conducted in the Middle Atlantic States, reports of hospital utilization by decedents were collected from both family informants and from each of the hospitals which provided the care. This double collection procedure was a deliberate feature of the design of the pilot study even though it added to the cost of conducting the pilot study. It was anticipated, however, that the duplicate reports from hospitals and family informants would provide valuable data for purposes of deriving efficient survey procedures for the proposed extension of the pilot study to a national mortality survey.

Comparison of Reports From Hospitals and Family Informants

First, the possibility was explored of collecting the hospital utilization information from the family informants only without any recourse to hospital records. In this connection, the admissions to general hospitals reported by informants and hospitals were compared and the findings are summarized below.

A total of 687 admissions to general hospitals during the year before death was reported either by informants or by the hospitals for the 695 decedents in this study. The hos-

Table 3. Comparison of the number of admissions to general hospitals reported by informants and hospitals by sex and age of the decedent

Sex and age	Number of admissions				Percent difference	
	Reported by either the informant or hospital	Reported by both the informant and hospital	Reported by hospital only	Reported by informant only	(Hospital informant)	
					Gross difference	Net difference
All deaths--	687	475	170	42	31	19
Male, under 65 years-----	207	123	74	10	41	31
Female, under 65 years-----	128	88	32	8	31	19
Male, 65 years and over-----	202	148	39	15	27	12
Female, 65 years and over-----	150	116	25	9	22	11

pital and informant reports agreed on about two thirds of the admissions. About 6 percent of the admissions were reported by the informant only and about 25 percent were reported by the hospitals only. Thus, the net difference in the number of admissions reported by hospitals and informants was about 19 percent more admissions reported by hospitals. The gross and net differences in reporting of admissions were greater at ages under 65 years than at older ages and they were greater for males than for females (table 3).

Of the 42 admissions reported by informants that were presumed not to be reported by hospitals, 26 refer to decedents for whom at least one admission was reported by a hospital, but not reported by informants. It seems likely that most of these 26 admissions were in fact reported by hospitals, but, because of reporting errors made by the informants, a match could not be established. The hospital reports refuted a few admissions reported by informants such as those for persons dead on arrival at the hospital and for persons who received outpatient care only. Nine admissions reported by informants were not confirmed either because the hospital did not return the survey form or because the hospital was not queried owing to the cutoff date of the survey.

Of the 170 admissions that were not reported by the informants, about one third represented deaths for which no report was obtained from the informant and two thirds represented deaths for which a report was received from the informant but the particular admission was not reported. An

informant report was not obtained for 78 deaths or about 11 percent of the 695 deaths in the sample. Twenty six of these deaths represented cases in which the informants did not respond to the survey and 52 were deaths in which the respondent was not queried, either because they were infant deaths 1 week or less of age (17 deaths) or because an informant was never identified (35 deaths).

The large net underreporting of admissions by informants as compared with the number reported by hospitals makes it apparent that a survey of informants alone would not have provided satisfactory data, and that a survey of hospitals is indicated in order to obtain accurate data. As a matter of fact, the estimates of hospital utilization by decedents that will be presented in this report are based entirely on the episodes of hospitalization reported by the hospitals themselves which provided the care.

Having established the need for collecting reports directly from the hospitals that provided care, the possibilities were explored of eliminating entirely or reducing the extent of the survey of informants. Since these possibilities differed according to whether or not death occurred in a hospital, separate explorations were made on this basis.

Data Collection Procedures for Deaths Occurring in Hospitals

For deaths occurring in hospitals, there were 3 sources from which information was collected

about the hospital experience of the decedent during the 12-month period prior to death:

- (a) Hospitals reported on the death certificate in which death occurred.*
- (b) Family informants reported on the death certificate or identified by the funeral director.
- (c) Other hospitals in which the decedent received care prior to death which had been identified by the institution of death, family informant, or another hospital.

Of the hospital utilization during the reference year by persons who died in hospitals, about 87 percent of the discharges and about 84 percent of the nights of care in general hospitals were provided and reported by the hospitals in which death occurred (table 4). Thus a survey of the hospitals in which death occurred would by itself have provided most of the data pertaining to gen-

eral hospital care for these decedents. About 8 percent of the hospital utilization was in general hospitals referred to by the institution of death. Only about 5 percent of the hospital care during the reference year of persons dying in hospitals was based on reports from hospitals which no other source except the family informant identified. Less than 1 percent of the care was in hospitals reported in personal interviews with informants who did not reply to the mail survey.

In this study, about 63 percent of all discharges from general hospitals during the year of reference were discharges by death. This is a notable fact because the place of death is recorded on the death certificate and there would be no need to conduct a special mortality survey to learn of such hospital discharges.

Data Collection Procedures for Deaths Occurring Outside of Hospitals

For deaths that occurred outside of hospitals, the family informant was the only source identifiable from the death record from which to collect information on decedent's episodes of hospital care prior to death. Thus, unlike the deaths for which the death record identified a hospital as the place of occurrence, there is no practical way of eliminating the survey of family informants. Also there would be a need to conduct a survey of each of the hospitals reported by the informants in order to obtain accurate information on the number and dates of hospital episodes. A vital question is: How completely are the hospitals which were utilized prior to death reported in the survey of informants? Although an unequivocal answer is not available from the Mortality Survey conducted in the Middle Atlantic States, the following results are illuminating.

Of the utilization of general hospitals during the reference year by persons dying outside of hospitals during that year, over 90 percent of the discharges and nights of care was reported by hospitals identified by informants who responded to the mail survey (table 5). The remaining hospital utilization was reported by hospitals which were either identified by informants who responded to the personal interview or by other hospitals.

Unfortunately, queries were not mailed to some of the hospitals that were identified in the personal interview with family informants because the interviews were completed after the cutoff date of the hospital survey. Since the estimates derived from the Mortality Survey were based entirely on reports of hospitals that provided the hospital care, the estimates do not reflect the care received by these few cases. Assuming the informant reports of hospital utilization by these cases, the volume of hospital utili-

Table 4. Discharges and nights in general hospitals during the reference year for persons who died in hospitals, based on reports from hospitals queried in the prescribed order

Order of querying hospitals	Discharges	Nights
	Percent	
Total-----	100	100
1. General hospitals in which death occurred---	87	84
2. General hospitals reported by the institution of death---	8	9
3. General hospitals reported by the family informant-----	5	7

*A hospital is defined to include all medical institutions listed either in the Directory of the American Hospital Association (AHA) or in the State hospital plans prepared under the Hill-Burton Act. About 56 percent (389) of the deaths in the sample occurred in these hospitals--372 deaths occurred in AHA-listed hospitals. Deaths in general hospitals accounted for about 290 out of the 372 deaths in AHA hospitals.

able 5. Estimates of discharges and nights in general hospitals during the reference year for persons who died outside of hospitals, based on reports of hospitals queried in the prescribed order

Order of querying hospitals	Discharges	Nights
	Percent	
Total-----	100	100
1. Hospitals reported in mail survey of informants-----	91(83)	94(85)
2. Hospitals reported by other hospitals-----	2(2)	2(2)
3. Hospitals reported by personal interview survey of non-responding informants to the mail survey-----	7(15)	4(13)

NOTE: The numbers in parentheses have been adjusted for the hospital care provided by a small number of hospitals which were not included in the estimates because the hospitals were not queried.

zation by persons who died outside hospitals would have been increased by about 10-15 percent. The estimate of the volume of hospital utilization by all deaths would have been increased by less than 2 percent.

Conclusions on Experimental Findings

About 19 percent more hospital discharges were reported by hospitals than were reported by family informants. Actually, it appears that very few hospital discharges would have been missed if those reported by family informants only had been excluded. This finding has important implications concerning the design of efficient survey procedures to collect data on hospital utilization for a group of decedents.

For deaths occurring in hospitals, there is no need to conduct a survey of family informants. Based on this Mortality Survey it is estimated that about 95 percent of the utilization of general hospitals that would not be covered in the health survey was reported by the hospital identified as the place of death on the death certificate and by other hospitals referred by this source. About 5 percent of the utilization was reported by hospitals that would not have been identified except for the survey of family informants.

For deaths occurring outside of hospitals, it is necessary to conduct a survey of the family informants in order to identify the hospitals utilized by persons prior to death. It is subsequently necessary to conduct a survey of each of these hospitals in order to obtain accurate data on episodes of hospitalization. It appears, however, that a mail survey of informants without provision for followup by personal interview with nonrespondents would be sufficient. The utilization reported by hospitals that were identified in the interviews accounted for less than 2 percent of the estimated hospital utilization by the decedents during the reference year.

HOSPITAL UTILIZATION IN THE MIDDLE ATLANTIC STATES

The frequency of total utilization of general hospitals in the Middle Atlantic States during 1957 is equal to the sum of two quantities:

- the hospital utilization by the population that was alive at the beginning of 1958, and
- the hospital utilization by the population that died during 1957.

Estimates of hospital utilization by the population alive at the end of the reference year (i.e., alive at the end of calendar year 1957) were derived from the National Health Survey and estimates of hospital utilization by the population that died during 1957 were derived from the Mortality Survey.

Estimates Derived From the National Health Survey

Estimates of utilization of general hospitals by the civilian noninstitutional population (i.e.,

by persons whose usual place of residence is other than in institutions such as penal institutions, tuberculosis sanitariums, mental hospitals, etc.) by sex and 3 broad age groupings are shown in table 6. They are based on data collected in the regular household interviews conducted in the Middle Atlantic States by the National Health Survey during July 1957-June 1958. For convenience, the reference year is considered to be calendar year 1957. The amounts of hospital utilization are largest for the age group under 45 years and smallest for the age group 65 years and over. Variation in the population sizes among the various age groups is the factor most responsible for the noted differences in the frequency of hospital utilization by age. The total population size and frequency of hospital utilization were greater for females than for males. For the middle age group, the frequency of utilization of general hospitals was slightly greater by males

Table 6. Estimates of the utilization of general hospitals by sex and age based on household interviews conducted during July 1957-June 1958 in the National Health Survey: Middle Atlantic States

Sex and age	Civilian population* size (in thousands) in 1957	Hospital utilization (in thousands)	
		Discharges	Nights
Both sexes-----	32,660	2,951	29,227
0-44-----	22,215	1,934	14,108
45-64-----	7,445	723	10,098
65+-----	3,000	294	5,021
Male-----	15,909	1,105	12,809
0-44-----	10,900	625	5,665
45-64-----	3,632	366	5,466
65+-----	1,377	114	1,678
Female-----	16,751	1,846	16,418
0-44-----	11,315	1,309	8,443
45-64-----	3,813	357	4,632
65+-----	1,623	180	3,343

*Population figures by broad age groups for combined sex groups were taken from Bureau of the Census, Current Population Reports, Series P-25, No. 194, Table 1. Figures by sex and age were computed assuming the sex ratios in 1959 for the U. S. civilian population.

than by females but for the younger and older age groups, the utilization was substantially greater by females.

Estimates Derived From the Mortality Survey

Estimates of hospital utilization during 1957 by sex and broad age groupings by the population that died during 1957 in the Middle Atlantic States (table 7) were derived from the Mortality Survey. (Again, for convenience and for the purpose of comparison with National Health Survey household interview data the calendar year 1957 is taken as the reference year, even though the estimates are based on hospital experience of persons dying during April 1957.) On the average, about 658 discharges and 11,336 nights of care per 1,000 deaths were omitted from the estimates of utilization of general hospitals derived from the health survey. It is estimated that the 349,147 persons who died during 1957 in the Middle Atlantic States had 230,000 discharges and 3,958,000 nights of care during 1957. Consequently, this amount of hospital utilization was not covered in the National Health Survey household interviews.

The preponderance of deaths at the older ages is responsible for the fact that the number

of discharges and nights of care are 3 to 4 times greater for the group 65 years of age and over than for the groups under 45 years of age. Actually, the rate of utilization of general hospitals per 1,000 deaths is lower for the group 65 years and over than for the younger groups.* There were more male than female deaths and the frequency of utilization of general hospitals was greater for males than for females. Except for the younger age group, both the frequency and rates of hospital utilization by males exceed those for females.

Estimates of total utilization of general hospitals during 1957 in the Middle Atlantic States by sex and broad age groupings may be computed by adding the respective frequencies of utilization for the living population (table 6) to those of the population that died (table 7).

*It should be emphasized that the trend downward with advancing age in the rates of discharges and nights of care per 1,000 deaths reported here covers utilization of general hospitals only. Inclusion of utilization of long-term hospitals and nursing homes would probably affect the trend in rates of discharges and nights of care by age.

Table 7. Utilization of general hospitals during 1957 by decedents by sex and age:
Middle Atlantic States

Sex and age	Number of deaths in 1957*	Hospital utilization by decedents during 1957			
		Rate per 1,000 deaths		Frequency (in thousands)	
		Discharges	Nights	Discharges	Nights
Both sexes-----	349,147	658	11,336	230	3,958
0-44-----	47,173	847	10,277	40	485
45-64-----	95,398	794	15,670	76	1,495
65+-----	206,576	554	9,567	114	1,976
Male-----	193,790	690	12,312	134	2,387
0-44-----	27,784	693	9,346	19	260
45-64-----	60,005	853	15,315	52	919
65+-----	106,001	598	11,384	63	1,207
Female-----	155,357	616	10,044	96	1,560
0-44-----	19,389	1,090	11,740	21	228
45-64-----	35,393	691	16,298	24	577
65+-----	100,575	504	7,526	51	757

* National Office of Vital Statistics, Vital Statistics of the United States, 1957, Volume II, Table 60, pp. 15-16

Table 8. Annual rates of discharge and nights of care in general hospitals per 1,000 persons: National Health Survey estimates, unadjusted and adjusted to include experience of decedents by sex and age: Middle Atlantic States

Sex and age	Discharges			Nights of care		
	Rate per 1,000 persons		Percent increase	Rate per 1,000 persons		Percent increase
	Unadjusted	Adjusted		Unadjusted	Adjusted	
Both sexes---	90	98	9	895	1,016	14
0-44-----	87	89	2	635	657	3
45-64-----	97	107	10	1,356	1,559	15
65+-----	98	139	42	1,674	2,373	42
Male-----	69	78	13	805	955	19
0-44-----	57	59	4	520	544	5
45-64-----	101	115	14	1,505	1,758	17
65+-----	83	129	55	1,219	2,090	71
Female-----	110	116	5	980	1,073	9
0-44-----	116	117	1	746	766	3
45-64-----	94	100	6	1,215	1,368	13
65+-----	111	147	32	2,060	2,525	23

Adjustment of the
Health Survey Estimates

The health survey estimates of rates of discharges and nights in general hospitals during 1957 per 1,000 midyear population by age and sex, unadjusted and adjusted, to include the hospital utilization of the population that died during 1957 are presented in table 8. The adjustments of the health survey estimates for the omission of hospital utilization of decedents are greater

for males than for females, and for both sexes the adjustments increase markedly with advancing age. The adjustment for deaths had minimal effect, at ages under 45 where the rates of hospital utilization, based on the health survey, are increased by less than 5 percent. At ages 65 and over, however, the increases in the hospital rates due to the adjustment are very substantial. The hospital rates at these ages are increased by 20 to 30 percent for females and by more than 50 percent for males.

Table 9. Percentage of discharges and nights in general hospitals not covered in the National Health Survey by sex, age, and place of death

Sex and age	Volume not covered in survey	Percent		
		Total	Deaths occurring in hospitals	Deaths not occurring in hospitals
Discharges				
Both sexes-----	230,000	100	88	12
0-44-----	40,000	100	95	5
45-64-----	76,000	100	92	8
65+-----	114,000	100	83	17
Male-----	134,000	100	87	13
0-44-----	19,000	100	92	8
45-64-----	52,000	100	92	8
65+-----	63,000	100	82	18
Female-----	96,000	100	89	11
0-44-----	21,000	100	97	3
45-64-----	24,000	100	90	10
65+-----	51,000	100	85	15
Nights				
Both sexes-----	3,958,000	100	87	13
0-44-----	488,000	100	92	8
45-64-----	1,496,000	100	88	12
65+-----	1,974,000	100	84	16
Male-----	2,398	100	88	12
0-44-----	260,000	100	90	10
45-64-----	919,000	100	90	10
65+-----	1,219,000	100	85	15
Female-----	1,560,000	100	85	15
0-44-----	228,000	100	95	5
45-64-----	577,000	100	85	15
65+-----	755,000	100	82	18

Hospital Utilization by the Population That Died Inside and Outside of Hospitals

It was hypothesized that of the hospital utilization by decedents during 1957 considerably more would be utilized by the persons dying in hospitals than by the persons dying elsewhere. The hypothesis was confirmed by the results of the Mortality Survey (table 9). About 88 percent of the discharges and nights of care utilized by decedents and not counted in the health survey were accounted for by persons who died in hospitals. In contrast, only about 56 percent of the deaths occurred in hospitals. For discharges the percentage varies with the age of the decedent, ranging from 83 percent for the age group 65 years and over to 95 percent for those under 45. This variation is due largely to the fact that the

percentage of deaths occurring in general hospitals decreases with advancing age. This trend probably reflects greater utilization of specialized long-term hospitals and nursing homes by the ill and infirm at the older ages.

The rates of discharges and nights of care in general hospitals per 1,000 deaths occurring in hospitals was roughly five times greater than those per 1,000 deaths occurring outside of hospitals (table 10). It will be noted that the rates of discharges per 1,000 deaths occurring in hospitals is less than 1,000 for the older age groups. The explanation is that utilization of general hospitals only was counted in computing these estimates. Thus, there were a number of persons dying in hospitals, particularly at the older ages, for whom terminal discharges were not counted because death occurred in nongeneral hospitals.

Table 10. Annual rate per 1,000 deaths of discharges and nights in general hospitals during the reference year for persons dying during the year by sex, age, and whether or not the death occurred in a hospital: Middle Atlantic States

Sex and age	Deaths in hospitals			Deaths outside hospitals		
	Estimated number	Discharges per 1,000 deaths	Nights per 1,000 deaths	Estimated number	Discharges per 1,000 deaths	Nights per 1,000 deaths
Both sexes---	196,093	1,036	16,921	153,054	186	3,448
0-44-----	33,244	1,127	13,556	13,929	185	2,667
45-64-----	57,023	1,228	23,263	38,375	156	4,468
65+-----	105,826	906	15,627	100,750	198	3,163
Male-----	105,580	1,102	19,764	87,960	206	3,361
0-44-----	17,171	1,000	13,676	10,613	190	2,381
45-64-----	34,442	1,386	24,157	25,563	154	3,462
65+-----	54,217	955	18,866	51,784	234	3,505
Female-----	90,263	954	14,740	65,094	159	3,571
0-44-----	16,073	1,276	13,414	3,316	167	3,667
45-64-----	22,581	977	21,841	12,812	160	6,560
65+-----	51,609	850	12,000	48,966	158	2,779

Conclusions Regarding Hospital Utilization in the Middle Atlantic States

According to the Mortality Survey, there were 658 discharges and 11,336 nights of care per 1,000 deaths that were not included in the

estimates of utilization of general hospitals derived from the household interviews of the National Health Survey. For the 350,000 deaths that occurred in the Middle Atlantic States during 1957, it is estimated that about 230,000 discharges and almost 4 million nights of hospital utilization were not covered in the estimates derived from

the health survey. When the National Health Survey estimates of utilization of general hospitals during 1957 are adjusted to include the experience of decedents, discharges were increased by about 9 percent and nights of care by about 14 percent.*

By age, the size of the adjustment was greater for the older group; by sex, the size of the adjustment was greater for males. The reason for this is largely due to the fact that the death

rate increases with advancing age and it is larger for males than for females.

Place of occurrence of death is another variable correlated with the frequency of utilization of general hospitals by the decedents. Deaths occurring in hospitals represented only slightly more than half the total number of deaths but they accounted for more than four fifths of the hospital utilization not covered in the health survey.

DERIVING ESTIMATES FROM THE MORTALITY SURVEY

As already indicated, data on hospital utilization during a 12-month period prior to death were obtained for a sample of about 2½ percent of the deaths that were registered in the vital statistics offices of the Middle Atlantic States during April 1957. Estimates of hospital utilization during 1957 by the population that died during that year were derived from these data. Since the sample was not selected from all deaths occurring throughout the year, it was necessary to assume that hospital utilization during the 12 months preceding death for persons dying in April was representative of the utilization by persons dying during the other months of the year. Specifically, it was assumed that the probability that a person received hospital care on the i th day ($i=0, 1, \dots, 364$) preceding death was the same for persons dying in every month during 1957 regardless of whether the hospital utilization occurred in calendar year 1957 or 1956.

This assumption would have been unnecessary had the estimates been derived from an alternative survey design involving (a) the selection of a sample of deaths from those occurring throughout the calendar year 1957, and (b) the

exclusion of hospital utilization during the period prior to calendar year 1957. However, this alternative survey design had two disadvantages. It would have increased the duration of the period required to collect the data by almost a full year and it would have provided information on hospital utilization for a period prior to death averaging only about 6 months. The former disadvantage by itself contraindicated the alternative design because results were needed as quickly as possible. The latter disadvantage would have had the effect of increasing the sampling error of the estimate.

Estimating Process

Define p_i as the probability that a person who died during some specific reference year had utilized a general hospital (i.e., received a night of care or was discharged) on the i th day preceding death ($i = 0, 1, \dots, 364$). Then \bar{u} , the average hospital utilization during the reference year per death that occurred during that year is

$$(1) \bar{u} = \sum_{i=0}^{364} p_i - \sum_{i=0}^{364} \frac{1}{365} p_i$$

The first term of the formula, $\sum p_i$, represents the expected number of times that a person dying during the reference year utilized a general hospital during the full 12-month period preceding death. The second term of the formula, $\sum \frac{1}{365} p_i$, represents the expected number of times that the utilization during the 12-month period prior to death was made prior to the reference year.

Hence, the difference between the two terms is the expected number of times that a person dying during the reference year utilized general hospitals during the same year. In other words, the difference is the expected utilization of hospitals per death during the reference year that is not covered by the health survey.

*There is a definitional difference between a discharge as used in the Mortality Survey and that used in the National Health Survey. The National Health Survey does not define an event as a hospital episode or discharge unless the person spends at least one night in the hospital. Thirty-eight discharges were counted in the Mortality Survey that by definition would not have been counted in the health survey because the admission and discharge occurred on the same day. One of these discharges occurred on the day before death and 37 were discharges by death. Had these discharges been excluded in the Mortality Survey, the estimate of discharges per 1,000 deaths not covered in the health survey would be 603. The adjustment factor would be about 8 percent. The revised estimates per 1,000 deaths occurring within and outside of medical institutions would be 941 and 183, respectively.

Estimates of the p_i 's were derived from the information collected for the 695 deaths in the sample. For example, the probability of discharge on each of the i days preceding death was estimated as follows. Discharges within a 12-month period prior to death that were reported by hospitals for the deaths in the sample were distributed by days prior to death on which the discharge occurred and each of these frequencies was divided by 695. In a similar manner the probabilities of nights of hospital utilization on successive days preceding death were estimated from the sample. The estimated values, \hat{p}_i 's, were substituted for p_i 's in formula (1) to obtain the estimate \bar{u}' .*

The estimated volume of hospital utilization during 1957 by the persons who died during that year was obtained by multiplying the mean estimate \bar{u}' by D , the total number of deaths during the reference period.

$$(2) \quad U' = D \bar{u}'$$

The value of D used is the number of deaths that occurred in the Middle Atlantic States during 1957 obtained from Vital Statistics of the United States, 1957, U. S. Department of Health, Education, and Welfare, Public Health Service, National Office of Vital Statistics, Volume II.

Daily Variation in Hospital Utilization Within the Last Year of Life

Within the 12-month period prior to death, there is a very marked increase in the daily utilization of general hospitals as the day of death approaches (table 11). The daily discharge rate per 1,000 deaths increases gradually from less than 1 during the twelfth month before death to

about 3 on the day before death. However, on the day of death the rate is about 400. The daily rates for nights of hospital utilization range from about 15 during the twelfth month before death to more than 350 on the day of death. For nights of care, the rates are about the same for experiences between 6-12 months before death. The rates increase steadily during the 6 months prior to death.

It will be noted that on the day of death, the probability of a discharge is greater than that for a night of care in a general hospital. This difference is accounted for by persons who died on the same day that they were admitted to the hospital; they were counted as having been discharged on the day of death, but they were not counted as having spent that night in the hospital.

As shown in table 11, for virtually all periods during the 1-year interval before death, the level of hospital utilization is greater for deaths occurring in hospitals than for other deaths. The difference, however, in the level of hospital utilization between the types of deaths is greater for nights than for discharges.

The difference in the daily rates between the two types of deaths is obviously greatest on the day of death. It will be observed, however, that the rate of utilization of general hospitals on the day of death is not 100 percent for deaths occurring in hospitals, nor is it zero for deaths occurring outside of hospitals. There were a number of hospital deaths that did not occur in general or short-term hospitals; these were not counted as having utilized a general hospital on the day of death. On the other hand, there were a few deaths that did not occur in the hospital but had been discharged on the day of death from a general or short-term hospital; these were counted as having utilized a general hospital on the day of death.

Because the probability of hospital utilization increases sharply toward the end of the last year of life, the hospital utilization during a specific year of reference for persons who die during that year accounts for most of the volume of utilization during the entire 12-month period before death (table 12). For example, considering all persons who died in the Middle Atlantic States during 1957, 83 percent of all their discharges and 74 percent of all their nights of care during the 12 months preceding death actually took place during 1957.

*A somewhat simpler method that did not involve deriving estimates of the p_i 's was used in verifying the computations

$$\bar{u}' = \frac{1}{d} \sum_{\lambda=1}^d \sum_{i=0}^{364} \left(1 - \frac{i}{365}\right) u_{\lambda i}$$

where d symbolizes the number of deaths in the sample and where

$$u_{\lambda i} = \begin{cases} 1 & \text{if the } \lambda^{\text{th}} \text{ death utilized a hospital on the } i^{\text{th}} \text{ day} \\ 0 & \text{if the } \lambda^{\text{th}} \text{ death did not utilize a hospital on the } i^{\text{th}} \text{ day} \end{cases}$$

Table 11. Daily rates of utilization of general hospitals per 1,000 deaths during selected periods prior to death according to whether or not death occurred in a hospital: Middle Atlantic States, 1957

Period prior to death	Daily rates per 1,000 deaths					
	Discharges			Nights of care		
	Total	Deaths in hospitals	Deaths outside hospitals	Total	Deaths in hospitals	Deaths outside hospitals
0-1 days-----	417.3	740.4	6.5	366.9	650.4	6.5
1-2 days-----	2.9	2.6	3.3	328.1	578.4	9.8
2-3 days-----	1.4	2.6	0.0	300.7	532.1	6.5
3-4 days-----	1.4	2.6	0.0	271.9	480.7	6.5
4-5 days-----	0.0	0.0	0.0	256.1	452.4	6.5
5-6 days-----	0.0	0.0	0.0	236.0	416.5	6.5
6-7 days-----	2.9	0.0	6.5	211.5	370.2	9.8
0-1 week-----	60.8	106.9	2.3	281.6	497.2	7.5
1-2 weeks-----	3.5	3.3	3.7	185.0	307.4	29.4
2-3 weeks-----	2.1	2.9	0.9	156.2	250.5	36.4
3-4 weeks-----	2.1	2.9	0.9	121.9	195.0	28.9
0-4 weeks-----	17.1	29.0	2.0	186.2	312.5	25.6
4 weeks-2 months-----	1.9	2.3	1.3	86.7	134.8	25.6
2-3 months-----	1.5	1.5	1.5	52.2	77.3	20.3
3-4 months-----	1.3	1.7	0.9	37.4	49.0	22.7
4-5 months-----	1.0	1.2	0.7	33.9	47.0	17.2
5-6 months-----	1.0	1.0	0.9	23.6	27.8	18.2
6-7 months-----	0.6	0.8	0.2	15.9	17.1	14.4
7-8 months-----	0.7	1.2	0.1	16.7	25.5	5.5
8-9 months-----	0.8	1.1	0.4	19.1	28.5	7.1
9-10 months-----	0.5	0.3	0.6	12.0	14.5	8.9
10-11 months-----	0.6	0.8	0.4	13.0	16.5	8.7
11-12 months-----	0.6	0.7	0.5	16.3	21.6	8.0
Sample size	695	389	306	695	389	306

Table 12. Discharges and nights in general hospitals within a 12-month period prior to death by sex, age, and whether or not the care was received during the reference year. Deaths during 1957: Middle Atlantic States

Sex and age	Total (in thousands)	Percent		
		Total	Not received during refer- ence year	Received during reference year
Discharges				
Both sexes-----	279	100	17	83
0-44-----	49	100	17	83
45-64-----	94	100	20	80
65+-----	136	100	15	85
Male-----	166	100	19	81
0-44-----	26	100	14	86
45-64-----	64	100	21	79
65+-----	77	100	18	82
Female-----	112	100	14	86
0-44-----	23	100	14	86
45-64-----	30	100	17	83
65+-----	59	100	11	89
Nights				
Both sexes-----	5,379	100	26	74
0-44-----	712	100	32	68
45-64-----	2,050	100	25	75
65+-----	2,617	100	24	76
Male-----	3,313	100	28	72
0-44-----	432	100	40	60
45-64-----	1,235	100	26	74
65+-----	1,648	100	27	73
Female-----	2,046	100	22	78
0-44-----	280	100	19	81
45-64-----	817	100	15	75
65+-----	949	100	20	80

Effect of the Length of the Reference Period in the Health Survey

This study has indicated that the National Health Survey estimates of hospital utilization in the Middle Atlantic States should be adjusted by about 9 percent to include the experience of persons who died during the reference period of 12 months prior to the interview. The following shows how the omission of decedent experience affects the health survey results when reference periods of different lengths are used.

The average volume of hospital utilization during the reference period of R days per person dying during the period is

$$(3) \bar{u}_R = \sum_{i=0}^{R-1} p_i - \sum_{i=0}^{R-1} \frac{i}{R} p_i$$

where p_i is the probability of hospital utilization on the i th day prior to death.

Assume that independent estimates of hospital utilization during a time period of kR days are derived from two types of health surveys, one having reference periods of kR days and the other having a reference period of R days' duration. In the former, a single survey is conducted at the end of the reference period of kR days. In the latter k surveys are conducted at intervals of R days during the period of kR days. The estimate of hospital utilization by the living population during the reference period of kR days derived from the k surveys each with a reference period of R days' duration would be larger than

that derived from the single survey with a reference period of kR days. The reason is that the single survey would cover a smaller portion of the hospital utilization during the kR days by the deaths that occurred during that period.

For the survey having a reference period of kR days, \bar{u}_{kR} is the hospital utilization per death during the kR -day period that would not be covered by the health survey results. For the survey having a reference period of R days, $k\bar{u}_R$ is the hospital utilization per death that would not be covered. According to formula (3) the expected difference between the hospital utilization per death during the time period of kR days that would not be covered in a single health survey with a reference period of kR days and k health surveys each covering a reference period of R days is

$$(4) \bar{u}_{kR} - k\bar{u}_R = (k-1) \sum_{i=0}^{R-1} i p_i + \sum_{i=R}^{kR-1} (kR-i) p_i$$

From the viewpoint of maximizing the coverage of hospital utilization by decedents, the reference period in the health survey, obviously, should be minimized. This gain would, however, have to be weighed against the loss due to collecting less information per person in the health survey. The effect of the latter would be to increase sampling errors of the estimates of hospital utilization derived from the health survey.

Table 13. Estimates of hospital utilization by decedents not covered in the health survey during a reference period of specified duration of less than 1 year compared with utilization during a reference period of 1 year's duration: Middle Atlantic States, 1957

Duration of reference period	Hospital utilization by decedents not covered in health survey			
	Discharges		Nights of care	
	Per 1,000 deaths	Percent	Per 1,000 deaths	Percent
1 year-----	658	100	11,336	100
6 months-----	572	87	8,772	77
3 months-----	508	77	6,370	56
1 month-----	451	69	3,328	29
2 weeks-----	432	66	1,980	17
1 week-----	422	64	1,226	11

The duration of the reference period of 1 year in the National Health Survey is not necessarily permanently fixed. It is therefore of more than purely theoretical interest to compare the estimates of discharges and nights of care presented in this report with those that would have been obtained assuming reference periods of shorter duration in the health survey (table 13).

As was to be expected, the rates of discharges and nights of care decrease without exception with decreases in the duration of the

reference period in the health survey from 1 year to 1 week. It is noteworthy, however, that the reductions in discharges are relatively small compared with the reductions in the nights of care. For a reference period of 1-week duration, the reduction is less than 40 percent for discharges and about 90 percent for nights. The explanation is that, within the 12-month period prior to death, a very much larger proportion of the discharges than of the nights of care occur on the day of death.

SAMPLING VARIABILITY OF ESTIMATES DERIVED FROM THE MORTALITY SURVEY

Variability of Hospital Utilization by Decedents

The estimates presented in this report were derived from sample data and consequently the estimates are subject to errors due to sampling variability.

The previous section contains an exposition on the method of deriving estimates of \bar{u} the average volume per death of hospital utilization that is not covered in the health survey. The method assumed that all persons who died during 1957 had the same probability, p_i of utilizing a general hospital on the i^{th} day prior to death ($i=0,1,\dots,364$). Under this assumption the sampling variance of \bar{u} the estimate of \bar{u} , was found to be

$$(5) \sigma_{\bar{u}}^2 = \frac{1}{d} \left[\sum_{i=0}^{364} \left(1 - \frac{i}{365}\right) p_i + 2 \sum_{i>j=0}^{364} \left(1 - \frac{i}{365}\right) \left(1 - \frac{j}{365}\right) p_{ij} - \bar{u}^2 \right]$$

*This is equivalent to writing $\sigma_{\bar{u}}^2 = \frac{1}{d} \sigma_{u_{\lambda}}^2$

where u_{λ} is the derived number of decedent discharges in the reference year for the λ^{th} of d discharges. When the experience is restricted to the terminal episode only, joint probabilities are not involved and $\sigma_{u_{\lambda}}^2$ is simplified to

$$\sigma_{u_{\lambda}}^2 = \sum_{i=0}^{364} p_i \frac{[(700-i+1)(1)]^2}{4(365)^2} - \bar{u}^2$$

where p_i ($i=1, \dots, 363$) is the proportion of the decedents who were admitted to the hospital on the

reference period in the health survey from 1 year to 1 week. It is noteworthy, however, that the reductions in discharges are relatively small compared with the reductions in the nights of care. For a reference period of 1-week duration, the reduction is less than 40 percent for discharges and about 90 percent for nights. The explanation is that, within the 12-month period prior to death, a very much larger proportion of the discharges than of the nights of care occur on the day of death.

Population variances were estimated from the sample by the formula,

$$(6) S_{u_{\lambda}}^2 = \sum_{i=0}^{364} \left(1 - \frac{i}{365}\right) \hat{p}_i + 2 \sum_{i>j=0}^{364} \left(1 - \frac{i}{365}\right) \left(1 - \frac{j}{365}\right) \hat{p}_{ij} - \bar{u}'^2$$

where \hat{p}_{ij} is the proportion of d deaths in the sample hospitalized (i.e., discharged or utilized a hospital overnight) on both the i^{th} and j^{th} days before death, and \hat{p}_i is the proportion of the sample hospitalized on the i^{th} day before death. The estimates of the standard deviations of discharges and nights of care by age and sex of the decedent and by whether or

i^{th} day before death, and p_{364} is the proportion that were admitted 364 days or more prior to death.

The estimated sampling variance of the quantity \bar{u}' becomes then, $S_{\bar{u}}^2 = \frac{1}{d} S_{u_{\lambda}}^2$.

The relative sampling errors (coefficient of variation expressed in percent), obtained from the formula

$$V_{\bar{u}} = 100 [S_{\bar{u}}^2 / (\bar{u}')^2]^{\frac{1}{2}}$$

are assembled in table 17.

not death occurred in a hospital is presented in table 14. Since the utilization of general hospitals is about 5 times greater for deaths occurring in institutions than for deaths occurring elsewhere, the standard deviations are considerably higher for estimates of the former than for estimates of the latter. The standard deviations of discharges are about 50 percent greater for hospital deaths, and on the average, the standard deviations of nights of utilization are more than twice as large for hospital deaths than for nonhospital deaths.

The calculation of $S_{u\lambda}^2$ was verified directly from the distribution of deaths by their hospital utilization during the reference year as follows

$$(7) S_{u\lambda}^2 = \sum_{\lambda=1}^d \frac{(u_{\lambda} - \bar{u}')^2}{d-1}$$

$$\text{where } u_{\lambda} = \sum_{i=0}^{364} (1 - \frac{1}{365}) u_{\lambda i}$$

is the hospital utilization during the reference year of the λ th decedent in the sample. The

random variable $u_{\lambda i}$ is equal to 1 if the λ th decedent was hospitalized on the i th day before death. It is equal to 0 if he was not hospitalized on the i th day before death. The distributions of decedents in the sample by their expected number of discharges and nights of utilization during the reference year are presented in tables 15 and 16, respectively.

Sampling Errors

The percent sampling errors (coefficients of variation) of the estimates of discharges and nights of care by age and sex of the decedent and whether or not death occurred in a hospital are presented in table 17. For each of these classes of decedents, the relvariance of the sample estimate \bar{u}' was computed by the formula

$$(8) \text{Rel Var } (\bar{u}') = V_{\bar{u}'}^2 = \frac{S_{\bar{u}'}^2}{(\bar{u}')^2}$$

The formula assumes simple random sampling with replacement.

Table 14. Standard deviations of estimates of hospital utilization during the reference year for decedents by sex and age and whether or not death occurred in a hospital

Sex and age	Standard deviation					
	Discharges			Nights		
	Total	Deaths in hospitals	Deaths outside hospitals	Total	Deaths in hospitals	Deaths outside hospitals
Both sexes-----	0.765	0.768	0.427	21.9	26.0	10.9
0-44-----	0.843	0.817	0.427	22.1	25.5	6.54
45-64-----	0.939	0.957	0.410	26.0	28.5	16.4
65+-----	0.630	0.597	0.435	19.4	24.3	8.53
Male-----	0.818	0.831	0.455	23.3	28.3	8.99
0-44-----	0.824	0.854	0.442	25.0	30.9	5.88
45-64-----	1.055	1.082	0.419	24.9	28.5	10.9
65+-----	0.635	0.564	0.476	21.7	27.2	8.55
Female-----	0.688	0.675	0.383	19.9	22.5	13.2
0-44-----	0.826	0.760	*	16.8	17.7	*
45-64-----	0.685	0.653	0.397	28.0	28.8	24.2
65+-----	0.622	0.629	0.382	16.2	20.0	8.54

* Sample size too small to estimate standard deviation.

Table 15. Percent distribution of decedents by their derived number of discharges during the reference year and whether or not death occurred in a hospital: Middle Atlantic States, 1957

Derived number of discharges during the reference year	Total	Deaths in hospitals	Deaths outside hospitals
Total-----	100.0	100.0	100.0
None-----	45.8	19.8	78.8
1/365 to 1/2-----	2.3	0.7	4.2
<u>183</u> to <u>364</u> -----	7.6	4.4	11.8
<u>365</u> <u>365</u>			
1-----	28.8	50.9	0.7
1 to 1 1/2-----	4.0	4.9	2.9
1 1/2 to 2-----	7.9	13.4	1.0
2 to 2 1/2-----	1.2	1.8	0.3
2 1/2 to 3-----	1.2	1.8	0.3
3 to 3 1/2-----	0.3	0.5	0.0
3 1/2 and over-----	1.0	1.8	0.0
Sample size	695	389	306
Mean-----	0.658	1.036	0.186
Standard deviation-----	0.765	0.768	0.427
Coefficient of variation-----	1.166	0.741	2.296

Table 16. Percent distribution of decedents by their derived number of nights of hospital care during the reference year, and whether or not death occurred in a hospital: Middle Atlantic States, 1957

Derived number of nights of care during the reference year	Total	Deaths in hospitals	Deaths outside hospitals
Total-----	100.0	100.0	100.0
None-----	49.4	26.2	78.8
1/365 to 10-----	22.1	31.9	9.8
10 to 20-----	9.1	12.6	4.9
20 to 30-----	6.6	8.7	4.0
30 to 40-----	3.1	4.9	1.0
40 to 50-----	2.6	4.4	0.3
50 to 60-----	2.6	4.1	0.6
60 to 70-----	1.5	2.3	0.3
70 to 80-----	0.9	1.5	0.0
80 and over-----	2.0	3.4	0.3
Sample size	695	389	306
Mean-----	11.3	16.9	3.45
Standard deviation-----	21.9	26.0	10.9
Coefficient of variation-----	1.93	1.54	3.16

Table 17. Percent sampling errors of estimates of discharges and nights of care in general hospitals during 1957 for persons who died during 1957 by sex, and whether or not death occurred in a hospital: Middle Atlantic States

Sex and age	Total			Deaths in hospitals			Deaths outside hospitals		
	Number in sample	Percent sampling error		Number in sample	Percent sampling error		Number in sample	Percent sampling error	
		Discharges	Nights		Discharges	Nights		Discharges	Nights
Both sexes--	695	4.5	7.4	389	3.8	7.5	306	13.1	
0-44-----	90	10.5	22.6	63	9.1	23.7	27	45.2	
45-64-----	191	8.6	12.0	114	7.4	11.5	77	28.6	
65+-----	414	5.6	10.0	212	4.6	10.7	202	15.6	
Male-----	396	6.0	9.5	216	5.2	9.8	180	16.8	
0-44-----	55	16.1	26.1	34	14.6	38.8	21	51.8	
45-64-----	122	11.2	14.7	70	9.5	14.2	52	38.7	
65+-----	219	7.2	12.9	112	5.7	13.6	107	20.0	
Female-----	299	6.5	11.5	173	5.5	11.6	126	20.7	
0-44-----	36	12.8	24.2	29	11.1	24.5	6	*	
45-64-----	68	12.0	20.7	44	10.1	19.7	25	41.6	
65+-----	195	8.9	15.4	100	7.6	16.6	95	25.0	

* Sample size too small to compute sampling error.

The coefficients of variation of the estimates of nights are more than 50 percent larger than those for discharges, and the coefficients of variation of the estimates of hospital utilization by

the nonhospital deaths are more than twice as large as the estimates of hospital utilization of the deaths occurring in hospitals.

SAMPLE DESIGN FOR A NATIONAL MORTALITY SURVEY

This project was undertaken to develop and to test a survey method to collect national statistics of hospital utilization during the 1-year period prior to death in order to derive estimates of hospital utilization by the decedents that are not covered in the National Health Survey. The experimental and substantive findings of the Mortality Survey in the Middle Atlantic States that have been presented in this report provide a basis for designing a national mortality survey that would assure stated precision in the estimates at minimum cost.

Optimum Stratification by Place of Death

Whether or not death occurred in a hospital is a fact discernible from the death certificate. It has been shown that there are substantial differences between hospital and nonhospital deaths in data collection costs, the variances of the utilization of general hospitals prior to death that are derived from the Mortality Survey. Optimum allocation of the national sample to two strata according to whether or not death occurred in a hospital is

or not death occurred in an institution would, in this instance, substantially increase the precision of the estimates per dollar costs as compared with estimates derived from a simple random sample.

The experimental findings of the mortality survey conducted in the Middle Atlantic States that were presented earlier indicate that it is not necessary to conduct a survey of family informants for deaths that occurred in hospitals. As a result, the per unit costs of data collection would be more than twice as large for nonhospital deaths than for hospital deaths because for the former it would be necessary to conduct a survey of both family informants and of the hospitals utilized by the decedent and for the latter it would be necessary only to conduct a survey of the hospitals utilized by the decedent.

On the other hand, the standard deviation of the distribution of deaths by hospital utilization not covered in the health survey in the Middle Atlantic States is about twice as large for hospital deaths as for nonhospital deaths. The ratio of the standard deviations of hospital deaths to nonhospital deaths is about 1.75 for discharges and about 2.5 for nights.

According to a well known formula⁶ the optimum allocation of the sample to strata that gives the most information per dollar is obtained when n_h , the number in the sample taken from the h^{th} stratum is

$$(9) \quad n_h = \frac{n N_h S_h / \sqrt{C_h}}{\sum_{h=1}^L (N_h S_h / \sqrt{C_h})}$$

where N_h , S_h , and C_h are the population size, standard deviation, and per unit cost in the h^{th} stratum and n is the total sample size over all L strata.

Assuming the findings of the Mortality Survey that the per unit data collection cost would be about one half as large for hospital deaths as for nonhospital deaths and that the standard deviation would be about twice as large for hospital deaths as for the nonhospital deaths, then the optimum allocation of the national sample decrees that about 80 percent of the deaths would be selected from the stratum of hospital deaths. Since about 60 percent of the national deaths occur in the hospitals, optimum allocation to strata implies that hospital deaths would be selected at almost triple the sampling rate of nonhospital deaths.

Additional economies by stratification would be realized if hospital deaths were subdivided into two strata according to whether or not death occurred in a general hospital. The per unit data collection costs for deaths occurring in nongeneral hospitals would be about the same as those for deaths occurring in general hospitals, but the standard deviation of the distribution of general hospital utilization would be considerably smaller for the deaths in nongeneral hospitals.

The utilization of general hospitals by the population that died in resident medical institutions in the Middle Atlantic States contributed very little to the estimates of utilization by the decedents presented in this report. From the conceptual viewpoint it is questionable whether persons dying in resident institutions should have been included in this Mortality Survey. Since estimates of general hospital utilization in the Middle Atlantic States derived from the National Health Survey covers only the noninstitutional population the estimates derived from the Mortality Survey that were used to adjust the health survey estimates for hospital utilization by decedents should have excluded the resident institution population also. Similarly, the national estimates of hospital utilization derived from the National Health Survey cover only the noninstitutional population.*

Sampling Errors of National Estimates

Assuming the variances and costs derived from the Mortality Survey conducted in the Middle Atlantic States and the optimum allocation of the sample stratified by place of death within and outside of hospitals, expected sampling errors were computed for estimates of hospital utilization by decedents that would be derived from national samples ranging in size from 1,000 to 10,000 deaths. Expected sampling errors are shown separately for discharges (table 18) and nights of care (table 19).

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Deaths in general hospitals	48
Deaths in other nonresident hospitals	3
Deaths in resident hospitals	10
Deaths outside of hospitals	39

Source: Vital Statistics of the United States, 1958. Vol. II, National Office of Vital Statistics, Department of Health, Education, and Welfare. In print.

Table 18. Expected sampling errors of estimates of hospital discharges during the reference year involving decedents by sex and age, that would be derived from a national mortality survey of specified sample sizes

Sex and age	Total number of deaths in the sample						
	1,000	2,000	3,000	4,000	5,000	7,500	10,000
	Coefficient of variation						
Both sexes----	3.1	2.2	1.8	1.6	1.4	1.2	1.0
0-44-----	6.9	4.9	4.0	3.5	3.1	2.6	2.2
45-64-----	5.7	4.0	3.3	2.9	2.6	2.1	1.8
65+-----	4.2	3.0	2.5	2.1	1.9	1.6	1.4
Male-----	4.2	3.0	2.5	2.1	1.9	1.6	1.4
0-44-----	11.4	8.1	6.6	5.7	5.1	4.2	3.6
45-64-----	7.3	5.2	4.3	3.7	3.3	2.7	2.4
65+-----	5.5	3.9	3.2	2.8	2.5	2.0	1.8
Female-----	4.5	3.2	2.6	2.3	2.0	1.7	1.5
0-44-----	8.2	5.8	4.7	4.1	3.7	3.0	2.5
45-64-----	8.2	5.8	4.8	4.1	3.7	3.0	2.6
65+-----	6.5	4.6	3.8	3.3	2.9	2.4	2.1

Table 19. Expected sampling errors of estimates of nights of hospital care during the reference year involving decedents by sex and age, that would be derived from a national mortality survey of specified sample sizes

Sex and age	Total number of deaths in the sample						
	1,000	2,000	3,000	4,000	5,000	7,500	10,000
	Coefficient of variation						
Both sexes----	5.6	4.0	3.3	2.8	2.6	2.1	1.8
0-44-----	15.6	11.0	9.0	7.8	7.0	5.7	5.0
45-64-----	9.3	6.6	5.4	4.7	4.2	3.4	3.0
65+-----	7.6	5.4	4.4	3.8	3.4	2.8	2.5
Male-----	7.0	5.0	4.1	3.5	3.2	2.6	2.3
0-44-----	27.0	19.1	15.6	13.5	12.1	9.9	8.6
45-64-----	10.7	7.6	6.2	5.4	4.8	3.9	3.3
65+-----	9.7	6.9	5.6	4.9	4.4	3.6	3.1
Female-----	9.2	6.5	5.3	4.6	4.2	3.4	2.9
0-44-----	17.5	12.4	10.1	8.8	7.9	6.4	5.6
45-64-----	17.3	12.2	10.0	8.7	7.8	6.3	5.5
65+-----	12.1	8.6	7.0	6.1	5.4	4.5	3.9

It is pertinent to consider, also, the sampling errors to be expected in national estimates of total utilization of general hospitals based on the sum of (a) estimates of utilization by the living population derived from the National Health Survey, and (b) estimates of utilization by decedents derived from a national mortality survey. The variance of the estimate of total hospital utilization is

$$(10) \sigma_{U'_T}^2 = \sigma_{U'_L}^2 + \sigma_{U'_D}^2$$

where U'_L is the estimated volume of hospital utilization by the living population and U'_D is the estimated volume of hospital utilization by decedents.

Standard errors of national estimates of selected statistics on the annual volume of hospital utilization based on the household interviews of the National Health Survey have been published (table 20). They are 5 to 10 times larger than the expected standard errors of comparable statistics for decedents based on a mortality survey of about 1,000 deaths. Consequently, the sampling error of estimates of total utilization of general hospitals would be completely dominated by the standard errors of the estimates derived from the National Health Survey.

Table 20. Standard errors of estimates of selected statistics on annual utilization of short-stay hospitals derived from the National Health Survey

The statistic	Sample estimate	Standard error
Total discharges from short-stay hospitals-	16,700,000	270,000
Total discharges from short-stay hospitals for persons 65 years of age and older-----	1,800,000	90,000
Total number of days of hospitalization for persons discharged from short-stay hospitals-----	143,300,000	7,400,000

Source: U. S. National Health Survey. Hospitalization, Patients Discharged From Short-Stay Hospitals, United States, July 1957-June 1958. Health Statistics, Series B-7. Public Health Service Publication No. 584-B7. Public Health Service, Washington, D.C., December 1958, p. 35.

SUMMARY AND CONCLUSIONS

Estimates of the annual volume of hospital utilization by the national population are based on data collected in the household interviews of the National Health Survey. The interviews obtain information on hospital utilization during a reference period of 12 months before the week of the interview by each resident in the household. The household interviews do not, however, obtain information on hospital utilization by the persons who would have been residents of the household except for the fact that they had died during the reference year. Thus, the annual estimates derived from the health survey do not include the hospital utilization by the population that died during the year. To obtain estimates of the total volume of hospital utilization, the estimates derived from the household interviews of the National Health Survey have to be supplemented by estimates of hospital utilization by decedents.

This report presents the results of a research project that was undertaken to develop and to test a method for ascertaining the volume

of hospital utilization during a reference year by persons who died during that year. The method involved collecting data on utilization of general hospitals during a 12-month period prior to death for a sample of decedents selected from death certificates registered in State Health Departments. There were two distinct phases to the project—a theoretical and an applied phase.

The theoretical phase of the project involved a consideration of hospital utilization during the last 12 months of life as a stochastic process. Formulas were derived for computing unbiased estimates of hospital utilization by decedents during a reference period of specified length and for computing the sampling variability of these estimates. The derivations are contained in Appendix II.

In the applied phase of the project, the Mortality Survey was conducted in the Middle Atlantic States involving 695 deaths that were selected from death certificates registered in the State Health Departments during April 1957. This sur-

vey was designed to serve as a pilot study to gain experience that would be needed in order to design an efficient national mortality survey. In the pilot study, information on hospital utilization during the 12-month period prior to death was collected from family informants and from hospitals utilized by the decedents. The data collection procedures of the pilot study were analyzed with the view to determining a procedure to be applied in the proposed national survey that would produce accurate national data at minimum costs. The data collected in the pilot study were used to derive estimates of general hospital utilization during the reference year by decedents as well as to derive sampling errors of these estimates. The estimates were then used to adjust those based on the National Health Survey household interview data.

According to the Mortality Survey, there were 658 discharges and 11,336 nights of care per 1,000 deaths that were omitted from the estimates of utilization of general hospitals derived from the household interviews of the National Health Survey. The health survey estimates of utilization of general hospitals during 1957, the reference year, were increased by about 9 percent for discharges and by about 14 percent for nights of care after adjustment for the 230,000 discharges and almost 4 million nights involving about 350,000 deaths that occurred in the Middle Atlantic States during 1957 (see footnote on p. 14).

By age, the size of the adjustment was greater for the older group, by sex, it was greater for males. Thus, for the population 65 years of age and older, the adjustment increased the health survey estimates by more than 25 percent for females and by more than 50 percent for males.

Place of death was another variable correlated with the frequency of utilization of general hospitals by decedents. Deaths occurring in hospitals represented only slightly more than half the total number of deaths but they accounted for more than four fifths of the hospital utilization not covered in the health survey. The utilization of general hospitals during the reference year was about 5 times greater for deaths occurring in institutions than for deaths occurring elsewhere.

Place of death was an important variable also from the viewpoint of data collection procedures. For deaths occurring in hospitals, it is not necessary to conduct a survey of family informants. It was estimated that about 95 percent of the utilization of general hospitals during the reference year was reported by the hospital identified on the death certificate as the place of death and by other hospitals referred by this source. Only about 5 percent of the utilization by these terminal cases was reported by hospitals

that would not have been identified except for the survey of family informants.

For deaths occurring outside of hospitals, it is necessary to conduct a survey of the family informants in order to identify the hospitals utilized by these decedents. It is necessary subsequently to conduct a survey of each of these hospitals in order to obtain accurate data on episodes of hospitalization. It appears, however, that a mail survey of informants without provision for followup by personal interview with nonrespondents would be sufficient. The utilization reported by hospitals that were identified in the interviews with informants accounted for less than 2 percent of the total hospital utilization during the reference year.

Assuming that the per unit data collection costs would be larger and the variability of the statistics would be smaller for nonhospital than for hospital deaths as found in the Mortality Survey, optimum allocation of the national sample indicates that hospital deaths should be selected at almost triple the sampling rate of nonhospital deaths.

The expected sampling errors of national estimates of utilization of general hospitals during the reference year by decedents are surprisingly small. The coefficients of variation of the estimates of discharges range from 1 to 3 percent and for nights of care from 2 to 6 percent for samples based on 1,000 to 10,000 deaths. The coefficients of variation are relatively small also for estimates by sex and broad age groups.

Sampling errors of national estimates of the annual volume of hospital utilization derived from the National Health Survey are considerably larger than the expected sampling errors of comparable statistics for the decedents based on a national mortality survey of about 1,000 deaths. In fact, the sampling error of estimates of total utilization of general hospitals would be dominated by the sampling errors of the estimates for the living population derived from the National Health Survey.

In planning for a national mortality survey, consideration should be given to a program for conducting a continuous national mortality survey in order to collect hospital utilization data for a relatively small sample of deaths annually. The Mortality Survey in the Middle Atlantic States demonstrated the feasibility of a method for estimating total hospital utilization by supplementing the statistics from the National Health Survey with estimates of utilization by decedents derived from a survey "anchored to the death record." Since the expected sampling errors of estimates to be derived from a national mortality survey appear to be negligible compared with the sampling errors of estimates based on the National Health Survey, a sample of a few thousand deaths

or less would be sufficient to assure reliable annual national estimates of total hospital utilization.

There would appear to be several advantages to a program for conducting a continuous mortality survey of hospital utilization of several years' duration. The one-time costs of getting the national survey underway during the first year would be amortized over several years. Annual estimates of total hospital utilization could be

derived for a series of years, and combining the data for 2 or more years would permit greater detail in the tabulations. In addition to the need for these data in order to supplement health survey data and thereby obtain estimates of total hospitalization, the data would appear to be potentially useful also as supplements to the regular mortality statistics derived from statistical data reported on the death certificate.

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APPENDIX I

GLOSSARY OF TERMS USED IN THIS REPORT

The following are definitions of selected terms relating to hospitalization and to the survey which have a specialized meaning in this report.

Terms Relating to Hospitalization in the Mortality Survey

Hospital.—A hospital is any medical institution listed either in the Directory of the American Hospital Association or in the State hospital plans prepared under the Hill-Burton Act.

General hospital.—A general hospital is one listed in the Directory of the American Hospital Association as providing a "general" type of service.

Hospital episode.—A hospital episode is a period of stay in a hospital beginning on the day of admission and ending on the day of discharge. The period of stay of a well, newborn baby is not considered a hospital episode. However, an admission and discharge on the same day is considered an episode.

Hospital admission.—A hospital admission is a hospital episode that began during a 12-month period prior to death. Patients dead on arrival (DOA) in the hospital are not counted as hospital admissions.

Hospital discharge.—A hospital discharge is a hospital episode that ended during a 12-month period prior to death.

Night of care.—A night of care is a night on which the decedent had been confined to a hospital during the

12-month period prior to death. A hospital episode for which the dates of admission and discharge are the same is not counted as a night of care.

Terms Relating to the Mortality Survey

Referral institution.—A referral institution is an institution other than the one in which death occurred from which the decedent had been discharged during the 12-month period prior to death. In the Mortality Survey, these institutions were identified either by the death certificate informant or by the institution listed on the death certificate as the place in which death occurred.

Informant.—The informant is the person whose name is recorded on the death certificate as having provided the funeral director with the personal information about the decedent for completion of the death certificate. The informant is usually some close relative of the decedent who is acquainted with the facts required for the death certificate.

The reference period.—The reference period is a calendar time period for which information on hospital utilization is collected. The reference period in the National Health Survey for hospital data is the 12 months prior to the week of interview. This same 12-month period is also considered the reference year for the Mortality Survey.

APPENDIX II

DERIVATION OF FORMULAS

Hospital Utilization Not Covered in the National Health Survey

Assume that every person in the household interview of the National Health Survey is interviewed at the same instant of time and that information is collected retrospectively for a reference period of R days' duration immediately preceding the interview. Then, U_R , the volume of hospital utilization during the reference period by persons who died during that time period is,

$$(1) U_R = \sum_{d=1}^R \bar{u}_d X_d$$

The symbol \bar{u}_d represents the average amount of hospital utilization (i.e., nights, discharges) during the reference period by the X_d deaths occurring on the d^{th} day of the reference period. In other words, formula (1) represents the volume of hospital utilization during the reference period for persons who died during that period, and consequently, not covered in the health survey.

Define p_i as the probability that a decedent had been hospitalized (i.e., spent a night in a hospital, or discharged from a hospital) on the i^{th} day preceding death ($i = 0, 1, \dots, R, \dots$). Assume that the p_i are constant over the reference period. Then \bar{u}_d is equal to $\sum_{i=0}^{d-1} p_i$. Substituting this expression for \bar{u}_d in formula (1), the expression becomes

$$(2) U_R = \sum_{d=1}^R X_d \sum_{i=0}^{d-1} p_i$$

Assuming that the deaths are uniformly distributed over the reference period, formula (2) becomes

$$(3) U_R = \frac{D_R}{R} \sum_{d=1}^R \sum_{i=0}^{d-1} p_i = D_R \sum_{i=0}^{R-1} \left(1 - \frac{i}{R}\right) p_i,$$

where D_R is the number of deaths occurring during the reference period of R days.

The size of U_R increases as R increases. This may be seen as follows: Consider a survey covering a reference period of kR days. According to formula (3)

$$\begin{aligned} U_{kR} &= \frac{D_{kR}}{kR} \sum_{i=0}^{kR-1} (kR-i)p_i \\ &= \frac{D_{kR}}{kR} \left\{ \sum_{i=0}^{R-1} (kR - ki + ki - i)p_i + \sum_{i=R}^{kR-1} (kR - i)p_i \right\} \\ &= \frac{kD_R}{R} \sum_{i=0}^{R-1} (R-i)p_i + \frac{D_{kR}}{kR} \left\{ (k-1) \sum_{i=0}^{R-1} ip_i + \right. \\ &\quad \left. \sum_{i=R}^{kR-1} (kR - i)p_i \right\} \end{aligned}$$

$$= kU_R + \frac{D_{kR}}{kR} \left\{ (k-1) \sum_{i=0}^{R-1} ip_i + \sum_{i=R}^{kR-1} (kR - i)p_i \right\}$$

It will be noted that the first term of the above formula is the hospital utilization by decedents that would not be covered in estimates derived from k weekly health surveys each covering a reference period of R days. The expected difference between the hospital utilization by decedents not covered in a single health survey covering a reference period of kR days and k health surveys each covering a reference period of R days is

$$(4) U_{kR} - kU_R = \frac{D_{kR}}{kR} \left\{ (k-1) \sum_{i=0}^{R-1} ip_i + \sum_{i=R}^{kR-1} (kR - i)p_i \right\}$$

Unbiased Estimate

Estimates of hospital utilization by decedents not covered in the health survey were based on a sample of d deaths selected from D deaths and were derived from the following formula.

$$(5) U' = \frac{D}{d} \sum_{\lambda=1}^d \sum_{i=0}^{R-1} \left(1 - \frac{i}{R}\right) u_{\lambda i}$$

$$\text{where } u_{\lambda i} = \begin{cases} 1 & \text{if the } \lambda^{\text{th}} \text{ decedent in the sample utilized} \\ & \text{a hospital (i.e., night or discharge) on the} \\ & \text{ } i^{\text{th}} \text{ day prior to death} \\ 0 & \text{if the } \lambda^{\text{th}} \text{ decedent did not utilize a hospi-} \\ & \text{tal on the } i^{\text{th}} \text{ day prior to death} \end{cases}$$

This estimate is unbiased,

$$\begin{aligned} E(U') &= \frac{D}{d} \sum_{\lambda=1}^d \sum_{i=0}^{R-1} \left(1 - \frac{i}{R}\right) E(u_{\lambda i}) \\ &= D \sum_{i=0}^{R-1} \left(1 - \frac{i}{R}\right) p_i = U \end{aligned}$$

Variance of the Estimate

Assume simple random sampling of deaths with replacement, then

$$\begin{aligned} \sigma_{U'}^2 &= \frac{D^2}{d^2} \sum_{\lambda=1}^d \text{Var.} \left[\sum_{i=0}^{R-1} \left(1 - \frac{i}{R}\right) u_{\lambda i} \right] \\ &= \frac{D^2}{d^2} \sum_{\lambda=1}^d \left[\sum_{i=0}^{R-1} \left(1 - \frac{i}{R}\right)^2 \sigma_{u_{\lambda i}}^2 + \right. \\ &\quad \left. \sum_{i \neq j=0}^{R-1} \left(1 - \frac{i}{R}\right) \left(1 - \frac{j}{R}\right) \sigma_{(u_{\lambda i} u_{\lambda j})} \right] \\ &= \frac{D^2}{d^2} \sum_{\lambda=1}^d \left[\sum_{i=0}^{R-1} \left(1 - \frac{i}{R}\right)^2 p_i (1 - p_i) + \right. \\ &\quad \left. \sum_{i \neq j=0}^{R-1} \left(1 - \frac{i}{R}\right) \left(1 - \frac{j}{R}\right) (p_{ij} - p_i p_j) \right] \end{aligned}$$

After some algebraic simplification, this becomes

$$\begin{aligned} (6) \sigma_{U'}^2 &= \frac{D^2}{d} \left\{ \sum_{i=0}^{R-1} \left(1 - \frac{i}{R}\right)^2 p_i + \right. \\ &\quad \left. \sum_{i \neq j=0}^{R-1} \left(1 - \frac{i}{R}\right) \left(1 - \frac{j}{R}\right) p_{ij} - \frac{U^2}{D^2} \right\} \end{aligned}$$

where p_{ij} is the probability of the decedent being hospitalized on both the i^{th} and j^{th} days prior to death.

Terminal Hospitalization Not Covered in the Health Survey

For the decedents, assume that there is a single discharge during the reference period prior to death and that the discharge is due to death. The number of discharges not covered in the health survey, μ , is

$$(7) \quad \mu = D \pi$$

where π is the probability of death occurring in a hospital, among D deaths occurring during the reference period. The nights not covered in the health survey μ is

$$(8) \quad \mu = \frac{D}{R} \sum_{i=0}^{R-1} (R-i) p_i = \frac{D}{R} \sum_{i=0}^{R-1} (R-i) \sum_{r=i+1}^R p_r$$

where p_r [$r=1, \dots, (R-1)$] represents the probability that a decedent was admitted to the hospital on the r^{th} day before death. p_R is the probability that a decedent was admitted to a hospital prior to $(R-1)$ days before death.

It follows that $p_i = \sum_{r=i+1}^R p_r$ when it is assumed that all

discharges are due to death; hence, the nights of hospitalization are clustered during a period of consecutive days prior to death.

Formula (8) may be simplified as follows:

$$\begin{aligned} (9) \quad \mu &= \frac{D}{R} \sum_{i=0}^{R-1} (R-i) \sum_{r=i+1}^R p_r \\ &= \frac{D}{R} \sum_{r=1}^R p_r \left[\sum_{i=0}^{R-1} (R-i) \right] \\ &= \frac{D}{R} \sum_{r=1}^R p_r \left[\sum_{i=1}^R i - \sum_{i=1}^{R-r} i \right] \\ &= \frac{D}{R} \sum_{r=1}^R p_r \left[\frac{R(R+1)}{2} - \frac{(R-r)(R-r+1)}{2} \right] \\ &= \frac{D}{2R} \sum_{r=1}^R (r)(2R-r+1) p_r \end{aligned}$$

The variance of μ' , an estimate of μ based on a simple random sample of d deaths selected with replacement is

$$(10) \quad \sigma_{\mu'}^2 = \frac{1}{d} \left(\frac{D}{2R} \right)^2 \left\{ \sum_{r=1}^R \left[(r)(2R-r+1) \right]^2 p_r - \mu^2 \right\}$$

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